# Efficient Cooling Systems for Motor & Motor Controller in Electric Vehicle A Review

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**Abstract -** *The thermal issue is a crucial consideration in the design of an appropriate cooling system for motors, and controllers of electric vehicles. The heat sources and the component geometry determine the thermal behavior. To reduce the overheating temperature of the motor & motor controller, various cooling technique are used. During transient thermal analysis, the time-temperature history data plays a significant role during simulation. In this work, the efficient cooling system for motor, controllers in Electric Vehicles related journal papers are reviewed, analyzed, and summarized by all the researchers that dealt with Electric Vehicles.*

***Key Words*: Electric Vehicles (EVs), Lithium-ion battery, Thermal Management, Air cooling, liquid cooling, simulation.**

## 1.INTRODUCTION

Electric vehicles have advanced quickly in recent years because of their potential to lessen the energy crisis and environmental issues. The lithium-ion battery serves as the source of electricity for the EV, and that performance influences the effectiveness of the EV[1]. In order to ensure that the temperature and temperature difference of the lithium-ion battery pack are within an acceptable range of degrees, the heat produced by the battery pack during operation needs to be swiftly dissipated. Consequently, the battery thermal management system is presented.[2]. Traditionally, the main objective of Thermal management in electric vehicles is used to prevent overheating of the power train subsystems. A more general view would be to consider climate control as part of a temperature control system[3]. A lithium-ion (Li-ion) battery would potentially be more compact as well as lighter comparing to a nickel-metal hydride (NiMH) battery. Moreover, they perform better than them in comparison[4]. Thermal management, including battery temperature control and cabinet air conditioning, is a major challenge for an electric car, as the traditional engine and oil tank are replaced by electric motors and battery packs[5].

With an air-cooled battery thermal management system, it is very easy to make a big temperature difference in the battery pack. due to the air's low specific heat. In this paper, Kai Chen et al. create a

straight forward design method for an air-cooled system that is symmetrical but has an uneven distribution of cell spacing to improve cooling performance. Researchers developed an electric vehicle thermal management system (EVTMS) that is intended to provide thermal comfort in the cabin, battery cooling, and engine cooling in order to make the most of the limited electricity available in EVs. Nevertheless, there are only a few examples in the literature for the design and performance evaluation of EVTMS[6].

The researchers investigated the effects of cooling circumstances and stack configurations on temperature distribution, and their findings demonstrated that an effective and economical cooling strategy in terms of distributed forced convection can enhance temperature uniformity and lower the maximum temperature inside the battery when compared to natural convection.[7]. Compared to ICEs, Electric motors are more effective in turning energy into propulsion for vehicles. In addition, electric cars can easily incorporate regenerative braking functions that could help recover nearly 20% of lost braking energy. Typical EV energy consumption ranges from 10 to 23 kWh/100 km, while fuel consumption for ICE vehicles ranges from 5.8 to 9.8 liters per 100 km. The design without a gearbox or with one gear allows electric cars to accelerate and brake more smoothly[8]. Among all the different kinds of cooling system that the authors found, the most efficient cooling system is the liquid cooling system.

## 2. Types of Electric Motor in EVs

### 2.1 DC MOTOR

A DC motor device is used on the principle of converting mechanical energy (electrical to mechanical). This can create magnetic fields, as can any motor type that has an internal mechanism to change the flow of current to the motor[11]. These motor's primary benefits include: dependable performance, low cost, simple and robust operation, and proven technology. Before the advent of sophisticated power electronics, DC motors were the preferred choice for variable speed applications. The main drawbacks include poor power density in comparison to competing technologies, costly carbon brush maintenance (about every 3000 hours), and low efficiency, but efficiency levels of over 85% can be reached[12].

### 2.2 Induction motors

Induction motors (IM), also referred to as squirrel cage motors or asynchronous motors, their primary benefit is their ease of construction. The rotor is made of a squirrel-cage-shaped stack of laminated steel with short-circuited aluminum bars[12]. Due to electromagnetic induction, the stator winding creates a magnetic field rotor is subjected to a magnetic field and a current is produced in it; this produces a torque[11]. The stator's magnetic field rotates a little faster than the rotor does. Rotor currents are induced by the slip between the rotor and stator frequencies, which results in motor torque[12].

### 2.3Permanent Magnet Synchronous Motor (PMSM)

This motor shares some similarities with a BLDC motor, but is driven by a sine wave signal to achieve lower torque ripple. The sinusoidal distribution of the poly phase stator windings generates a sinusoidal flux density in the air gaps that differs from the trapezoidal flux density of a BLDC motor[13]. Motor PMSM is divided into internal PMSM and surface mounted PMSM. A PMSM motor and a synchronous motor work similarly. They are highly conductive materials such as Samarium-Cobalt and Neodium-Iron-Boron and high permeability is ensured on permanent magnets, which is a very suitable material because due to economy and availability[11]. This motor can generate torque at zero rpm, is highly efficient and produces comparative high power density to an induction motor. However, this engine requires a drive to operate. This motor uses a variable frequency drive (VFD) to achieve high torque specifications at low speeds, high efficiency and density. The VFD control technique increases the system's complexity, which calls for careful consideration to precisely control its speed. Therefore, When compared to an induction motor, the price of this motor is slightly higher. These PMSMs utilize VFDs for high power applications, just as induction motors. They have been regarded as having a tremendous potential to compete with induction motors for EV and HEV applications due to their inherent high power density and high efficiency[13].

### 2.4 Synchronous Permanent Magnet Permanent

The rotor of permanent magnet (PM) motors is continuously magnetized. High magnetic fields are created in the air gap by PMs in the rotor without the need for excitation currents, producing a high power density. In non-self-excited synchronous motors, excitation currents are responsible for about half of the losses in the form of Joule losses. As a result of the absence of excitation currents, PM motors are intrinsically more efficient and require less cooling. As the excitation field does not need to be controlled, this results in more complicated control[12].An electrically commutated DC supply powers PM motors. The rectangular armature emf was produced by the consecutive commutation of the winding currents. Due to historical considerations, the terms "Brushless Permanent Magnet" (BPM) and "Synchronous PM Motors" (SPM) are still in use to describe devices with different back electromagnetic fields[12]. Synchronous motors are types of motors where the rotor shaft is coordinated with the supply current's frequency. The supply period and rotor period for these motors are identical[13]. The magnets can be mounted to the rotor using a variety of techniques. Magnets are typically positioned on the rotor surface of axial flux machines, although magnets can be mounted inside or outside of radial flux machines[12].

## 3. Simulation

Iron loss increases significantly due to the stator and rotor core's high frequency magnetic flux density. Studying the loss and temperature characteristics of high-speed PMSMs is thus a crucial component of their design. The high-speed IPM rotor's rotation causes air to flow through the air gap[14]. The stator and rotor are where heat is transferred via convection. The conductivity of a stationary fluid is utilized to mimic the thermal conductivity of flowing air[14].

Overheating, which can be causing irreversible demagnetization of PMs, is the main problems with high-speed permanent magnet motors[15]. As power density rises, so does power loss density. Windage loss is brought on by air friction as the rotor rotates. As the machine accelerates, its importance increases[16]. These various losses are evaluated by using ANSYS Maxwell and finite element (FEA) in two dimensions. Static analysis is originally utilized to resolve motor parameters like the PM flux linkage and the inductance table[17]. In order to help with winding and rotor heat dissipation, forced air cooling is achieved by pushing air axially into the machine from one end. This is done in accordance with thermal analysis, which treats electromagnetic losses as heat sources[16]. How hot the engine gets is primarily determined by its heat conductivity.. The material used for each motor component must have a comparable acceptable thermal conductivity. An exact computation of the loss and distribution is the cornerstone for an accurate simulation that measures the motor's thermal performance[18].

Even though PMSMs have benefits like lower rotor and shaft temperatures, analysis to guarantee no power loss, quicker ramp-up times, and continuous power up to maximum speed, installing a good cooling system is crucial to ensuring the motor's longevity and optimum driving performance[19]. Calculation of the heat sources of the actuator is done by means of a practical 2-D FE electromagnetic analysis weakly connected with thermal analysis.[20].

## 4. Battery management system in EVs

Batteries, which are composed of electrochemical cells that transform chemical energy into electrical energy, can be used to power a variety of electrical equipment. Currently, applications for electric vehicles use three different types of advanced batteries: lithium-ion, nickel-metal hybrid (NiMH), and nickel-cadmium (NiCd). The electrolyte in these batteries is either paste, gel, or resin. Graphite or carbon with a graphite component makes up the negative electrode. In a non-aqueous solution of a lithium-salt mixture, the free ions of the electrolytes are disseminated using a mixture of organic liquids, such as ethylene and propylene carbonate. The majority of cells are cylindrical and prismatic in shape. The cylindrical cell design offers higher consistency, lower prices, and simpler production due to the complexity of the manufacturing process, but it limits the capacity to less than 4 Ah. The temperature of the Li-ion battery must be kept under control. Any heat imbalance or overheating will result in problems for the battery. The Li-ion battery's authorized operating temperature range, which is suitable for use in electric cars, is around 220°C to -60°C. They found through an experimental investigation that 55°C was enough to cause 55% of the stored power to fade[21].All batteries may effectively and instantly transmit heat to the coolant since the majority of direct cooling systems immerse the battery pack in the coolant. The weight of the entire battery pack is too high when the coolant in the battery pack is completely poured in. According to the area required for the battery pack and the cooling requirements, the inlet and outlet channel diameter, battery spacing, and coolant volume should be built. The numerical simulation results for the cooling plate's five channels were enough to keep the temperature variance and maximum temperature within a manageable range[22]

In comparison to traditional batteries, the lithium-ion battery has the benefit of requiring almost no maintenance over the course of its lifespan. Scheduled cycling is not required, and the battery has no memory effect. To ensure the safe operation of these batteries, a safety device needs to be fitted into each pack. This part, sometimes referred to as the battery management system (BMS), manages the peak voltage of each cell when charging and prevents the cell voltage from dropping too low during discharging. To prevent battery failures, various BMS types are used. A battery monitoring system is the most common type, recording crucial operational data like voltage, current, internal battery temperature, and ambient temperature while the battery is being charged and discharged. For this kind of application, the BMS should incorporate battery monitoring and protection systems, a system that keeps the battery ready to supply its maximum power when needed, and a system that can extend the battery's life. When the voltage reaches a stable value and the battery is nearly full, the battery enters the constant voltage (CV) stage. The charger maintains a steady voltage until the battery is fully charged while the battery's current deteriorates progressively[23].

Hybrid electric car battery packs should last 15 and 10 years, respectively. Battery packs can function in a range of 30 to 52 degrees Celsius. According to recent research, the best temperature range for LiBs is between 15 and 35 degrees Celsius, with a maximum temperature difference of 3 degrees Celsius between battery cells[24].Hybrid electric car battery packs should last 15 and 10 years, respectively. Battery packs are temperature-compatible. BMS manages battery packs that are connected either internally or externally. Calculations are conducted regarding battery numbers, and typical measurements are taken for cell voltages, pack currents, pack voltages, and pack temperatures between 30 and 52 degrees Celsius. According to recent research, the best temperature range for LiBs is between 15 and 35 degrees Celsius, with a maximum temperature difference of 3 degrees Celsius between battery cells[25]The electrolyte must offer the greatest amount of lithium ion movement under use conditions. The environment in which the batteries must operate can vary from, for instance, 30 C for a car that has been parked in extremely cold weather for a time to +60 C for a battery that has warmed owing to a combination of ambient factors and heat produced by charging[26].Compared to lithium cobalt oxide batteries, it has a 33% lower capacity and a shorter lifespan, but its chemistry provides better thermal stability. Due to their wide temperature range, which enables them to operate between +60 °C and 30 °C, these batteries are substantially less likely to have a thermal runaway. Capacity is lost after the active material has transformed into the inactive phases as a result of parasitic chemical interactions, but the issue is complex and challenging to model using straightforward techniques. The temperature range varies depending on the chemical used in each specific battery. Operating the batteries outside of their ideal temperature range can have a negative impact on their maximum charge capacity and the total number of cycles they can provide[26].

## 5. Conclusions

This research review demonstrates a cooling system for motors, and controllers of electric vehicles. Among all the different kinds of cooling systems, the most efficient cooling system is the liquid cooling system. The overheating, which can cause irreversible demagnetization of permanent magnets, is a major issue with high-speed permanent magnet motors. The review paper would also critically evaluate the current state of research in thermal analysis and identify the gaps, limitations, and opportunities for future research.

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